Pedobiologia, Bd. 17, S. 169—174 (1977)

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# Potassium and calcium cycling by *Eupterotegaeus rostratus* (Acari: Cryptostigmata)

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With one figure

(Accepted: 10. 4. 1976)

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## 1. Introduction

Recent studies in an aspen woodland ecosystem in the Canadian Rockies have elucidated the biology of particular soil organisms and their roles in energy flow and, to a lesser extent, in chemical cycling. To date emphasis has been put on Enchytraeidae (Dash and Cragg 1972), Testacea (Lousier 1974), fungi (Visser and Parkinson 1975) oribatid mites (Mitchell 1974), and carabid beetles (Carter 1975). As part of the latter study, the roles of a carabid and of an oribatid in chemical cycling were compared. The data on the carabid are presented by Carter and Pritchard (1976) and this paper presents the results for an oribatid. The latter organism, *Eupterotegaeus rostratus* Higgins et Woolley, was chosen because it was readily identifiable and its biology (see Mitchell 1974) known.

Radionuclides have recently been used as analogues of stable elements to elucidate the roles of organisms in chemical cycling (after Reichle 1969). Elimination rates of the radioactive analogues may be combined with data on consumer biomass and concentrations of stable elements in consumers and in their food to estimate loss of chemical elements by egestion (van Hook 1971). Ingestion rates of food and of chemical elements also may be studied with the aid of radionuclides. Whole body concentrations of radionuclides at equilibrium (when radionuclide intake equals egestion) may be combined with estimates of elimination to calculate ingestion.

These types of study require that when a radioactive tracer is fed to an organism, the organism's body burden (after the organism is removed from the tagged food) decreases steadily over time. Then the rate of elimination may be measured by regression analysis. It is important that results of egestion and ingestion studies obtained from the use of radionuclides be compared with those obtained by other methods. These matters are considered further in the present study which describes elimination patterns of cesium-137 and strontium-85 by adults of the oribatid *Eupterotegaeus rostratus* and aspects of its role in the cycling of chemical elements.

## 2. Methods

### 2.1. Radionuclide elimination experiments

Cesium-137 and strontium-85 were used as metabolic analogues of potassium and calcium, respectively, so as to describe elimination patterns and excretion rates in *Eupterotegaeus rostratus*. Several studies indicate that these radionuclides are suitable analogues of potassium and calcium. For example, REICHLE and CROSSLEY (1969) showed that biological half lives of $^{134}Cs$ and $^{42}K$ in a cricket were similar, although more $^{42}K$ was assimilated. GIST (1972) and REICHLE et al. (1970) cited evidence that in terrestrial organisms the behaviors of cesium and potassium on the one hand and that of strontium and calcium on the other are similar.

Litter and oribatid mites were collected from an aspen woodland soil in the Kananaskis Valley of Alberta (ca. 51°02′ N, 115°02′ W). The study area is described in detail by MITCHELL (1974). Litter, homogenized in a comminutor with 3 mm openings, was soaked in water and 18 $\mu$Ci of $^{137}CsCl_2$ and 10 $\mu$Ci of $^{85}Sr(NO_3)_2$/g of litter were added. The contaminated litter was well mixed and air dried and then added, with a spatula, to plastic boxes, 85 mm × 68 × 31, with plaster-charcoal substrates. Thirty adults of *Eupterotegaeus rostratus* previously kept at 15 °C for 12 hours, were added to each box. As the oribatid is fungivorous (MITCHELL 1974), it fed on fungi which had incorporated radionuclides from the labelled litter. After 24 hr, at 15 °C the contaminated litter with the oribatids was spread on cheesecloth on top of wire mesh and placed in simple Tullgren funnels. The oribatids were extracted with gentle heat into liquid scintillation vials, containing slightly moistened filter paper, over a period of one hour. The oribatids were then removed from the vials and liquid scintillation cocktail was added. The materials were then counted so as to check for egestion by the labelled oribatids during extraction. No contamination of the vials occurred.

Oribatids were separated into groups of six and each group was placed in a small gelatin capsule which was in turn placed in a test tube and counted in a two channel Packard Auto Gamma Counter. Only those oribatids with body burdens at least 10 times background were used in the experiments. Four such groups were killed by deep freezing and the remainder were removed from their test tubes and capsules and placed in non-contaminated litter in small plastic boxes, 22 mm × 22 × 18, with plaster-charcoal substrates and stored at 15 °C. Four groups were randomly chosen at intervals and the mites killed by deep freezing and counted in gelatin capsules in test tubes. Standards of $^{137}C$ and $^{85}Sr$ were counted with the samples during each counting run so as to check for machine malfunction. All strontium-85 counts were corrected for decay.

### 2.2. Estimation of parameters

Elimination of ingested radionuclides may occur in components. The elimination of two components occurs when there is not complete assimilation of a radionuclide and the unassimilated fraction is lost quickly from the gut in comparison with the slower rate of the fraction assimilated. Immediately after a single feeding on radioactive food, digestive assimilation ($p_2$) and the tissue component are equivalent (REICHLE 1969).

Two component elimination is described by the equation

$$A_t = A_o(p_1 e^{-k_1 t} + p_2 e^{-k_2 t}) \quad (1)$$

where $A_t$ is the radionuclide body burden at time t, $A_o$ is the initial body burden, $p_1$ and $p_2$ are the unassimilated and assimilated fractions ($p_1 + p_2 = 1$), respectively, lost at the rates $k_1$ and $k_2$ and e is the base of the natural logarithms (VAN HOOK and CROSSLEY 1969). Alternatively, the slow component may be described by linear regression analysis.

Food intake of the oribatid was estimated from the equation

$$I = k_2 Q_e M / p_2 Q_f \quad (2)$$

where I = the ingestion rate in mg/day (dry wt), $k_2$ = the elimination coefficient of the radionuclide from tissue per day; $Q_e$ the equilibrium concentration of the radionuclide in the consumer; $p_2$ the assimilated fraction; M the biomass of the consumer in mg/m² (dry wt) and $Q_f$ = the radionuclide concentration in its food.

## 3. Results and discussion

### 3.1. Cesium-137 and strontium-85 elimination

The pattern of elimination of $^{137}Cs$ and $^{85}Sr$ (Fig. 1) was of the two component type. Cesium-137 body burdens decreased sharply within two days to approximately 0.5 of the initial burden and decreased gradually after three days. The pattern for $^{85}Sr$ was similar. The fluctuations in body burdens of the mites, in part, resulted from the fact that different individuals were sampled and counted on each run. Because of the experimental design, it was not possible to count the same individuals repeatedly.

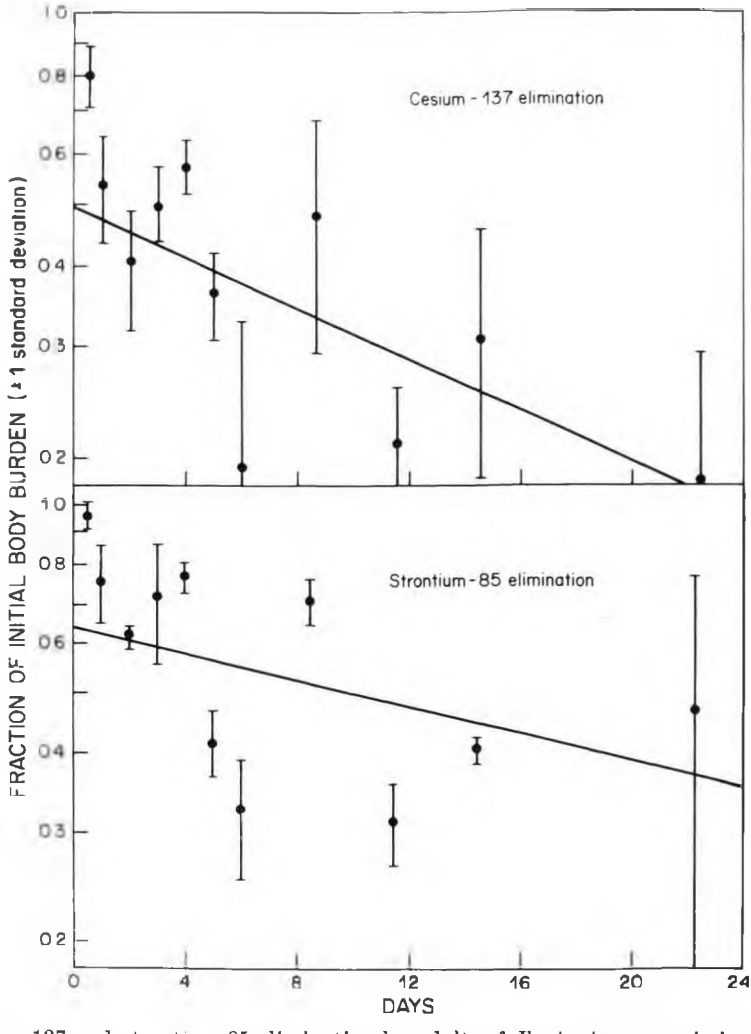


Fig. 1. Cesium-137 and strontium-85 elimination by adults of *Eupterotegaeus rostratus*. Each point represents a mean of four groups, each of six individuals, randomly selected from the experimenal population. For $^{137}Cs$, $p_2 = 0.485$ and $k_2 = 0.044$; for $^{85}Sr$, $p_2 = 0.632$ and $k_2 = 0.026$.

Estimates of parameters (± SD) described by equation 1 were obtained by non-linear regression analyses and were as follows: For $^{137}Cs$, $p_2 = 0.517 \pm 0.104$, $p_1 = 1 - p_2 = 0.483$, $k_1 = 1.40 \pm 0.81$/day and $k_2 = 0.041 \pm 0.025$/day. For $^{85}Sr$, $p_2 = 0.606 \pm 0.291$, $p_1 = 0.394$, $k_1 = 0.32 \pm 0.24$/day and $k_2 = 0.0046 \pm 0.041$/day.

A better estimate of $k_2$ for $^{85}Sr$, $0.026 \pm 0.022$/day, was obtained when the elimination data after day 1 were fitted by linear regression analysis; $p_2$ was 0.632. When the $^{137}Cs$ data were similarly fitted, estimates of $0.044 \pm 0.023$/day and 0.485 were obtained for $k_2$ and $p_2$, respectively. With the exception of $k_2$ for $^{85}Sr$, these parameter estimates were similar to those obtained by non-linear regression analyses.

### 3.2. Ingestion, potassium and calcium cycling

Food intake and hence chemical intake may be calculated from equation 2. The parameters $Q_e$ and $Q_I$ were measured in separate experiments (Carter unpubl., data summarised in Table 1) and M was 8.47 mg/m² (Carter and Cragg 1976). Food ingestion estimates of 0.110 and 0.028 mg fungi/m²/day were obtained when the $k_2$ and assimilation estimates (obtained by linear regression analysis) for the $^{137}Cs$ and $^{85}Sr$ data, respectively, were fitted to equation 2.

This method of measuring ingestion requires that the radionuclide concentrations in the consumer's food be known accurately. Fungivorous oribatids such as *Eupterotegaeus rostratus* were assumed to have fed mainly on microfungal mycelia, but the radionuclide turnover and distribution experiments summarized in table 1 indicated that such consumers fed not on microfungal mycelia but on other fungal stages. Although the body burden of the oribatid equilibrated before the end of the experiment it did not do so with radionuclide concentrations in the litter or in the microfungal mycelia. Also, included in Table 1 are data from the collembolan *Onychiurus subtenuis* NICOLET, which equilibrated in the same way as *E. rostratus*. Thus, these fungivores may have fed on fungal stages that were poor in $^{85}Sr$ and $^{137}Cs$.

Table 1. Concentration of cesium-137 and strontium-85 in litter, microfungal mycelia, and two fungivores from laboratory microcosms

| | dpm/mg dry wt ± 95% confidence limits | |
|---|---|---|
| | $^{137}Cs$ | $^{85}Sr$ |
| Litter | 117,150 ± 12,920 | 65,860 ± 13,860 |
| Micro-fungal mycelia | 79,390 ± 30,230 | 108,570 ± 45,430 |
| *Eupterotegaeus rostratus* | 11,390 ± 5,430 | 8,790 ± 5,300 |
| *Onychiurus subtenuis* | 12,050 ± 9,280 | 2,690 ± 500 |

Independent ingestion estimates were determined by MITCHELL (pers. comm.) and MITCHELL and PARKINSON (1976) based on gut content analyses. In 1972, maximum feeding activity occurred in the spring, remained high during the summer and declined markedly after September (MITCHELL 1974). Mean ingestion rate between mid-May and mid-July was approximately 0.376 mg/dry wt/$m^2$/day (allowing for 85% wet wt of their fungal food) and so adults ingested the equivalent of 4.4% of their standing crop $m^2$ day. During this two-month period the mean soil temperature was approximately 11 °C. Mean ingestion rate in mid-August was approximately 0 314 mg dry wt of fungi $m^2$ day with a mean soil temperature of 14 °C.

MITCHELL and PARKINSON (in press) assumed a gut clearance time of 0.5 days. In the present study, halftimes for gut clearance ($T^1_{/2}$) were calculated from the $^{137}Cs$ and $^{85}Sr$ elimination data using the relationship $T_{1/2} = \log_e 2/k$ and were found to be 0.5 days and 2.2 days, respectively. Total gut clearance time ($2T_{1/2}$) of $^{137}Cs$ is then twice that of MITCHELL and PARKINSON's figure for gut clearance. If the ingestion estimate, 0.110 mg $m^2$ day, based on the $^{137}Cs$ parameter estimates are used together with the chemical concentration data of AUSMUS and WITKAMP (1974) on microfungal mycelia to estimate chemical ingestion by the oribatid, then 0.110 mg of fungi contained ($0.110 \times 0.0332 \mu g$ Ca/mg = 0.0037 mg) calcium, ($0.110 \times 0.0024 \mu g$ K/mg = 0.00026 mg) potassium and ($0.110 \times 0.0004 \mu g$ Na/mg = 0.00004 mg) sodium. Thus, between mid-May and mid-July, ingestion of calcium, potassium and sodium would have been 0.112 mg, 0.008 mg and 0.001 mg/$m^2$/month, respectively.

The estimates of calcium ingestion reflect the high calcium levels in microfungal mycelia but, as indicated above, the oribatid may have fed on fungal stages that were low in $^{85}Sr$, also in calcium. The above calcium intake figure would then be too high. These points can only be elucidated by detailed studies on interactions between soil fungi and their consumers in concert with investigations on the turnover and distribution of chemical elements in various stages of soil fungi.

The amounts of chemical elements ingested by the oribatid were small in comparison with annual chemical input through leaf fall (estimated at $3.15 \times 10^3$ mg calcium, $0.96 \times 10^3$ mg potassium and $0.01 \times 10^3$ mg sodium/$m^2$; CARTER and CRAGG 1976). However, *E. rostratus* was but one of the many mycophages in the aspen woodland which included other oribatids (adults of *E. rostratus* accounted for only 0.4% of the total adult oribatids in the aspen soil [from MITCHELL 1974]), collembola, and enchytraeids (DASH and CRAGG 1972). The standing crops of calcium, potassium and sodium in the biomass of adult *E. rostratus* were 0.130, 0.015 and 0.023 mg/$m^2$, respectively (CARTER and CRAGG 1976).

Apart from the amounts of chemical elements that consumers ingest and recycle through egestion, oviposition, and mortality, consumers may also affect chemical flux by the organisms on which they feed. For example, it has been postulated that mycophages may stimulate microbial growth by their grazing activities (e. g., MacFadyen 1964; McBrayer and Reichle 1971) and may thus indirectly cause an increase in the amounts of chemical elements present in mycelia per $m^2$ during certain times of the year.

## 4. Summary . Zusammenfassung

Elimination of cesium-137 and strontium-85 as analogues of potassium and calcium, respectively, by adults of *Eupterotegaeus rostratus* Higgins et Woolley was studied in the laboratory. Assimilation was 49 % for $^{137}Cs$ and 63 % for $^{85}Sr$. During peak feeding, mid-May to mid-July, ingestion of calcium, potassium and sodium was calculated to have been 0.112, 0.008, and 0.001 mg/$m^2$/month, respectively, for a population of standing crop of 0.130 mg calcium, 0.015 mg potassium and 0.023 mg sodium, mg/$m^2$ respectively.

**Kalium- und Calcium-Kreislauf durch *Eupterogaeus rostratus* (Acari, Cryptostigmata)**

Die Elimination von Caesium 137 und Strontium 85 als Analoge von Kalium bzw. Calcium durch Adulti von *Eupterotegaeus rostratus* Higgins et Woolley wurde im Labor untersucht. Die Assimilationsrate betrug 49 % bei $^{137}Cs$ und 63 % bei $^{85}Sr$. Während der Hauptfreßzeit, Mitte Mai bis Mitte Juli, ergab die Schätzung für die Calcium-, Kalium- und Natriumaufnahme 0,112, 0.008 and 0.001 mg/$m^2$/Monat bzw. für die Population einer standing crop 0.130 mg Ca, 0.015 mg K und 0.023 mg Na per $m^2$.

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